©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Excursion Guide to RECCCE Workshop

Michael WAGREICH, Heinz A. KOLLMANN, Hans EGGER, Andrei F. GRACHEV &
Herbert SUMMESBERGER

The ecxursion route crosses three main units of the Eastern Alps, i.e., the Northern Calcareous Alps at Gams (Austro-Alpine Unit), the Helvetic Unit near Gmunden at the Rehkogelgraben, and the Rhenodanubian Flysch Zone as part of the Penninic units (Fig. 1).

During the Cretaceous to Paleogene, these units were arranged paleogeographically from north to south: the Helvetic and Ultrahelvetic units formed parts of the European shelf and continental slope to the north, the Penninic Rhenodanubian Flysch Zone was part of the Alpine Tethys south of the European continental margin, and the Northern Calcareous Alps formed parts of an active continental margin and orogenic wedge south/southeast of the Penninic realm.

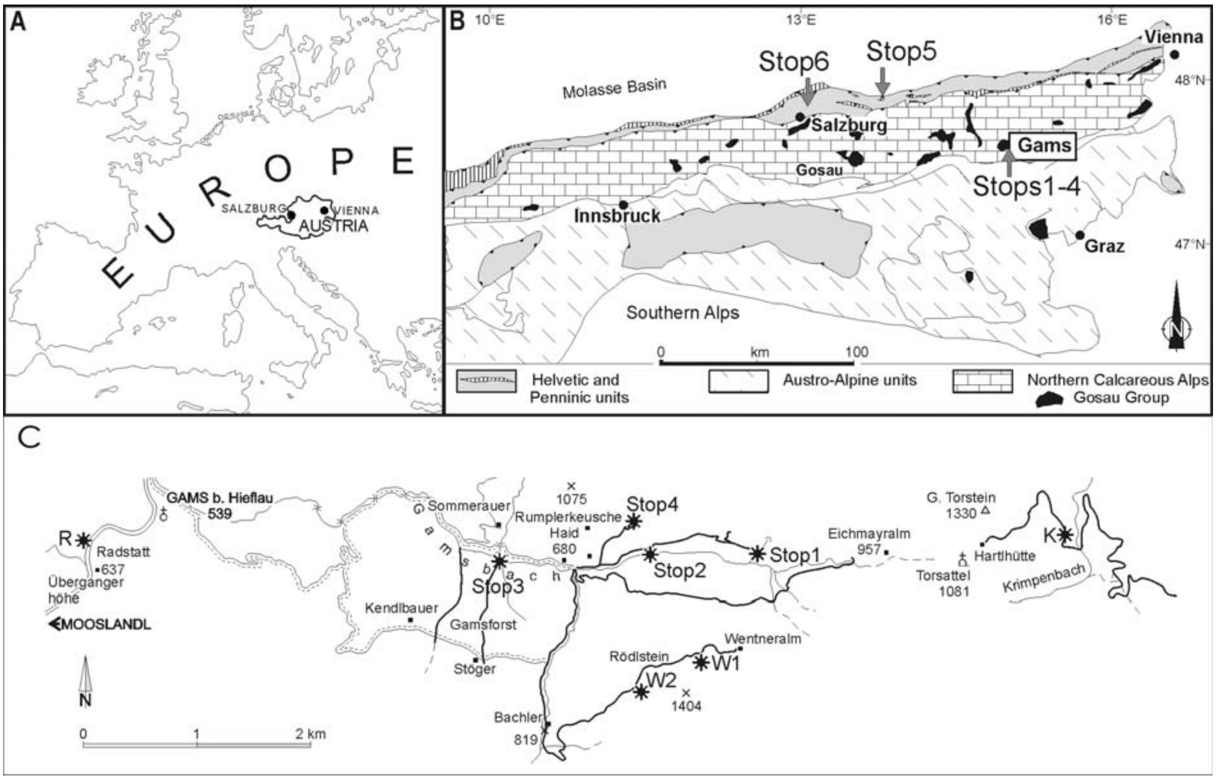


Fig. 1. The Gosau deposits at Gams are located between Salzburg and Vienna in Austria (1A and 1B). 1C: Map of the outcrops visited in the Gams area: Stop 1 Knappengraben K/Pg boundary, Stop 2 – Gamsbach K/Pg boundary, Stop 3 - Paleocene-Eocene boundary interval, Stop 4 – Maastrichtian cephalopod site at Haid. Additional points of stratigraphical interest in the Gams basin: ammonite sites Wentneralm (W1, W2), Krimpenbach (K) and Radstatt (R) (Summesberger & Kennedy, 1996; Summesberger et al., 1999).

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

The Gosau Group of Gams

The Gosau Group of the Northern Calcareous Alps was deposited in the northwestern Tethys realm during the Late Cretaceous and Paleogene (Wagreich & Faupl, 1994). Paleomagnetic inclination data and general plate tectonic reconstructions for these deposits suggest a paleolatitude of 20° to 30° N (Pueyo et al., 2007).
The Gosau Group comprises mainly siliciclastic and mixed siliciclastic-carbonate strata deposited after Early Cretaceous thrusting (e.g., Wagreich & Faupl, 1994). Deposition of the Gosau Group was the result of transtension, followed by rapid subsidence into deep-water environments due to subduction tectonic erosion at the front of the Austro-Alpine microplate (Wagreich, 1993, 1995). Within the Northern Calcareous Alps the Gosau Group unconformably overlies folded and faulted Triassic to Lower Cretaceous strata. Terrestrial to shallow-marine clastics prevailed during Late Turonian to Campanian, followed by deep-water sedimentation until the Eocene.

The Gosau Group of Gams (Fig. 2) consists of a terrestrial to shallow-marine part of Late Turonian to Early Campanian age (Lower Gosau Subgroup) and deep-marine Campanian to Lower Eocene deposits (Kollmann, 1964; Upper Gosau Subgroup). Outcrops of the Lower Gosau Subgroup are more or less restricted to the western part of the E-W-elongated outcrop belt ("western basin" of Kollmann, 1964; Kollmann & Summesberger, 1982). The following lithostratigraphic units have been distinguished based on Kollmann (1964), Siegl-Farkas & Wagreich (1997) and Egger et al. (2004):

(1) A basal unit of red alluvial conglomerates up to 70 m thick (Kreuzgraben Formation).

(2) A succession of shales and clays with rarely intercalated sandstones, and coaly clays, containing marine fossils, coal and jet (Schönleiten Formation; Kollmann & Sachsenhofer, 1998).

(3) A succession up to 400 m thick of grey shales containing coal seams, sandstone with serpentinite sands, Trochacteon and rudist limestones (Noth Formation; Upper Turonian; Siegl-Farkas & Wagreich, 1997).

(3) Several hundred meters of grey silty shales with rare sandstone tempestites (Grabenbach Formation; Upper Turonian - Santonian), containing ammonites and inoceramids (Kollmann & Summesberger, 1982; Summesberger & Kennedy, 1996).

(4) A transgressive succession of conglomerates, sandstones and grey shales (Krimpenbach Formation, Late Santonian - Late Campanian age, Summesberger et al., 1999; Wagreich, 2004).

(5) Deep-water shales and turbidites of the Nierental Formation, including turbidites and olisthostromes (Upper Campanian – Lower Paleocene) (Wagreich & Krenmayr, 1993, 2005).

(6) Sandstone-rich turbiditic successions (Middle Paleocene – Lower Eocene) (Egger et al., 2001, 2004).

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

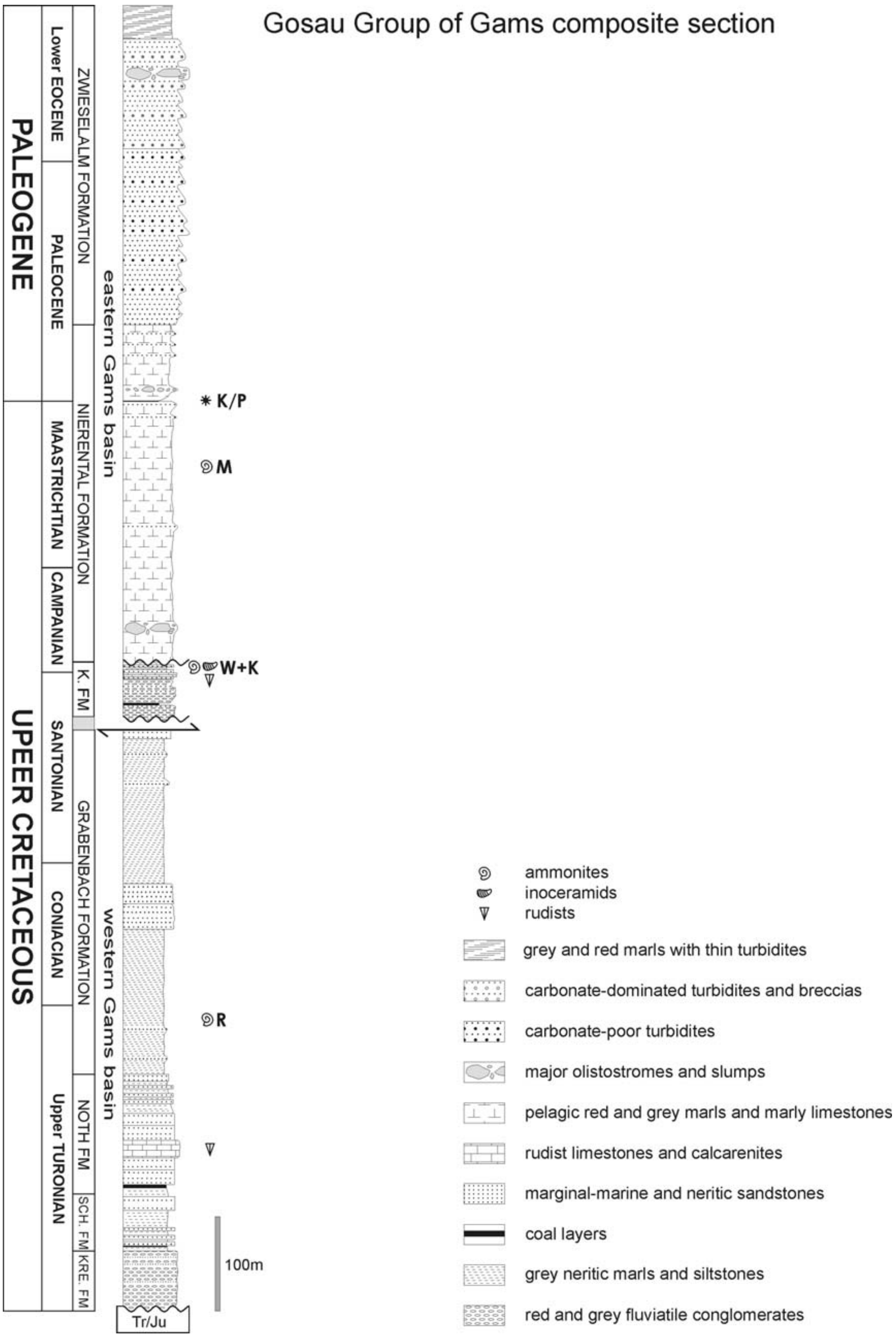


Fig. 2. Composite log of the Gosau Group of the Gams area (modified from Summesberger et al., 2009) (K. FM – Krimpenbach Formation; SCH. FM – Schönleiten Formation; KRE. FM – Kreuzgraben Formation; for abbreviations R, W, M, K/P see Fig. 1) (Summesberger et al., 2009).

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

RECCCE Excursion Day 1, Saturday, April 25, 2009

STOP 1 Cretaceous/Paleogene boundary at Knappengraben/Gams

Andrei F. GRACHEV & Heinz A. KOLLMANN

Topic: Cretaceous/Paleogene boundary section Gams 1
Lithostratigraphic unit: Nierental Formation (Upper Gosau Subgroup)
Age: Late Maastrichtian (CC26) – early Paleocene (NP1)
Tectonic unit: Untersberg nappe / Göller nappe (Tirolicum), NCA
Location: Outcrops along an abandoned forest road from Haid to Kronsteiner
Coordinates: Latitude 47^0 39.783 N, longitude $14^0$52.982 E, altitude 813.1 m
Specialities: first K/Pg boundary section recognized in that area; recent findings of geochemistry and mineralogy; discussion on impact and volcanism.
References: Lahodynsky (1988a,b), Grachev et al., 2005, 2007, 2008, 2009

The outcrop is located 700 m south of the abandoned farmhouse Kronsteiner (see: Austrian map 1:50.000, sheet 101, Eisenerz) at the crossing between the forest road and the Knappengraben torrent. It is protected by a fenced shelter.

Scientific background

An overview of the Basin of Gams and the stratigraphy of its late Cretaceous/Palaeogene rocks has been given by Kollmann (1964). Detailed studies on the K/T boundary of Gams have first been performed at the Knappengraben outcrop. The lithological section has been described by Lahodynsky (1988a,b). Nanno- and micropalaeontological work has been performed by Wicher (1956), Stradner & Rögl (1988), Wagreich & Krenmayer (1993), Egger et al. (2004), Grachev et al. (2005) and Korchagin & Kollmann in Grachev (2009).

Geological situation

In the outcrop which is currently protected by a fence, a section of the Nierental Formation across the K/Pg boundary is exposed. Beds are dipping at 40° towards SSE (ss 170/40). The base is formed by pale grey, late Maastrichtian shaly limestones with a well-defined ichnofauna (*Chondrites, Zoophycos, Thalassinoides*). The transitional layer consists of dark grey plastic clay containing small mica particles. It is overlain by grey clays and thin, yellowish to brown fine-grained sandstone layers.

The monolith

The major source of information of Grachev et al. (2005) and Grachev (2009) is the "monolith", a block cut out from this outcrop by members of the Department of Geology and Palaeontology of the Vienna Museum of Natural History. It represents a section of 23 cm across the K/Pg boundary.

***Mayaroensis* Zone**.The statigraphically lower part (layers A – I) consists of light grey shaly limestones. Dark spots of approximately 1mm in diameter are sections through *Chondrites*. The burrows are filled with dark boundary clay. Comparable traces are known from K/T boundary sections of Italy, France, Spain, Bulgaria and others and indicate an *Abathomphalus mayaroensis* or *Pseudoguembelina hariaensis* zones of the *Globotruncanidae* and *Heterohelicidae* standard zonation. Planktonic foraminifera, especially *Abathomphalus mayaroensis* and and *Globotruncanita stuarti*, suggests a position at the top of the Zone *Abathomphalus maryaensis*. It corresponds well with other East Alpine sections in the Bavarian Alps (Herm et al., 1981) and "Bed 9" in the Rotwandgraben of the Basin of Gosau, Austria (Peryt et al., 1993). Also in Tunisia (Keller, 1988) it was recorded close to the upper boundary of the Abathomphalus maryaensis Zone of the standard scale.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

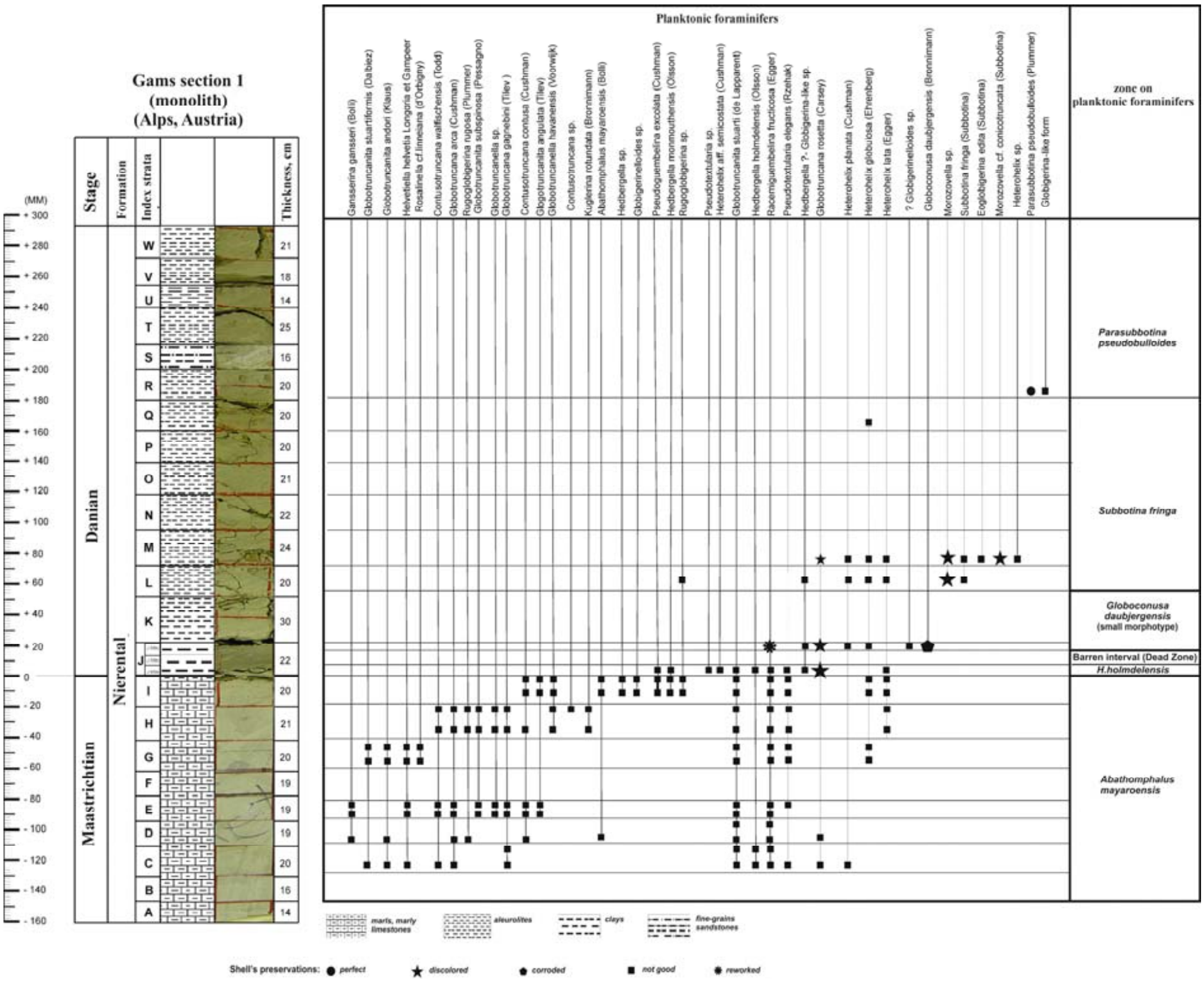


Fig. 3. Distribution of planktonic foraminifera in the monolith (Korchagin & Kollmann in: Grachev, 2009)

The foraminifera assemblage is characteristic for the *Globotruncanita stuarti* Zone, suggesting a position at the top of this zone. While *Gansserina gansseri* LO has been recorded in Gams slightly below the top of the marls underlying the boundary layer J, it extends to the top of the Maastrichtian in the El-Kef section (Tunisia). We therefore infer that the terminal Maastrichtian has been retained in the Gams section.

The K/Pg boundary clay (Layer J) has a thickness of about 2 cm. It is vertically heterogeneous and its texture varies according to its clastic content and the clay matrix distribution. For detailed examination, the layer was subdivided into 6 subunits of 2–3 mm thickness each. The following planktonic foraminifera zones have been recorded:

***Holmdelensis* Zone**. The lower part of the transitional clay of Gams (unit J) contains also an assemblage of small heterohelicids and hedbergellids including *H. holmdelensis* (Grachev, Korchagin, Kollmann et al., 2005). We therefore distinguish the *holmdelensis* Zone also in Gams and correlate it with the boundary clay in Spain. However, the redeposition of *H. holmdelensis* together with other typical Cretaceous planktonic foraminifers cannot be ruled out completely.

Barren interval (dead zone). This interval in the middle part of unit J comprises dark green to black clay. It is approximately 0.2 cm in thickness and lacks foraminifers. It is still premature to speculate about the geographical distribution of this interval because evidence is too scarce.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

***Globoconusa daubjergensis* Zone**. Lower boundary defined by FO of index species (= *Globoconusa daubjergensis* Zone in Grachev, Korchagin, Kollmann et al., 2005). The first appearance of *Globoconusa daubjergensis* in Gams is above the barren interval in the unit J.

***Fringa* Zone**. Unit K is a lens of grey, sandy clay with slickensides. It rests on the eroded top of the boundary clay and was produced by a submarine slide. It is overlain by yellow to brownish, fine-grained sandstone and grey clays containing *Subbotina fringa*. Therefore, *Globoconusa daubjergensis* occurs in Gams below the base of the fringa zone and therefore at a lower stratigraphical level.

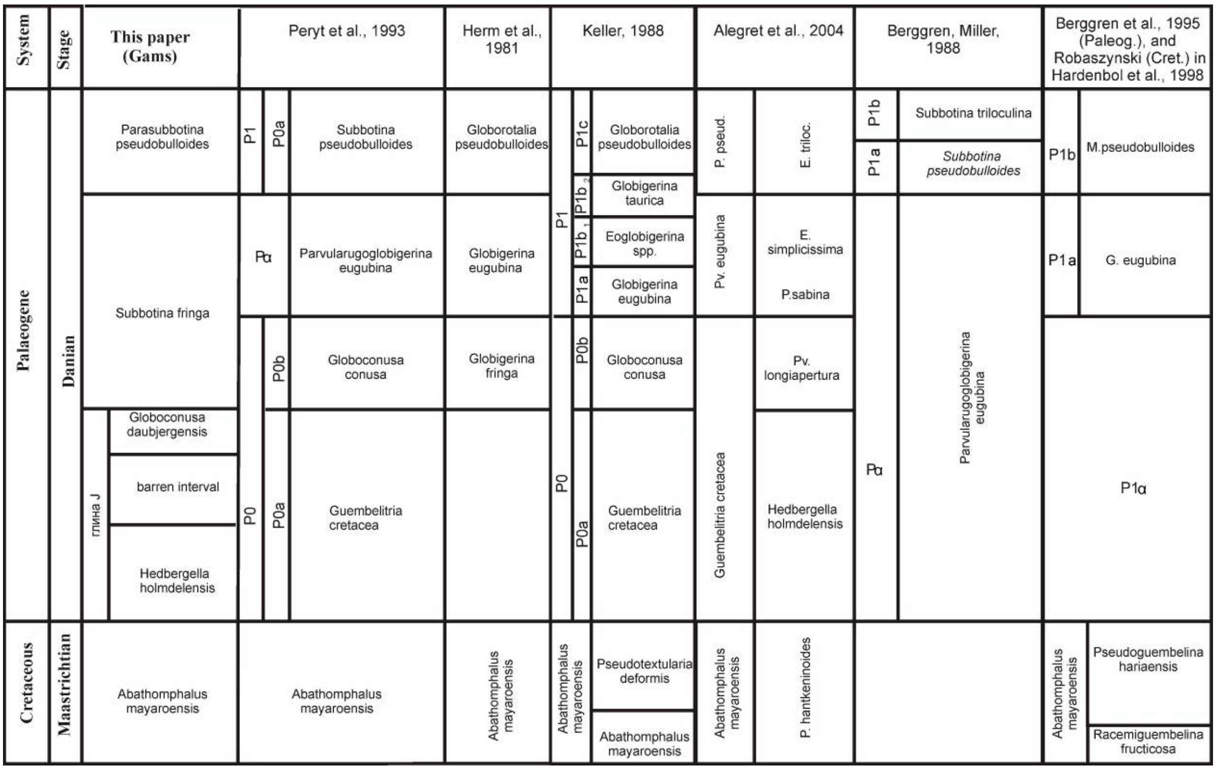


Fig. 4. Correlation chart of Cretaceous/Palaeogene boundary sections (Korchagin & Kollmann in: Grachev, 2009)

Distribution of foraminifera

The distribution chart of foraminifera (Fig. 3) shows that the extinction of genera began well before the accumulation of the boundary clay. The lower part of unit J shows an impoverished fauna of planktonic foraminifera while the benthic foraminifera remained diverse. *Globoconusa daubjergensis* appears first immediately above the barren zone and therefore below the base of the fringe zone (Grachev, Korchagin, Kollmann et al., 2005) and therefore at a lower stratigraphical level.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

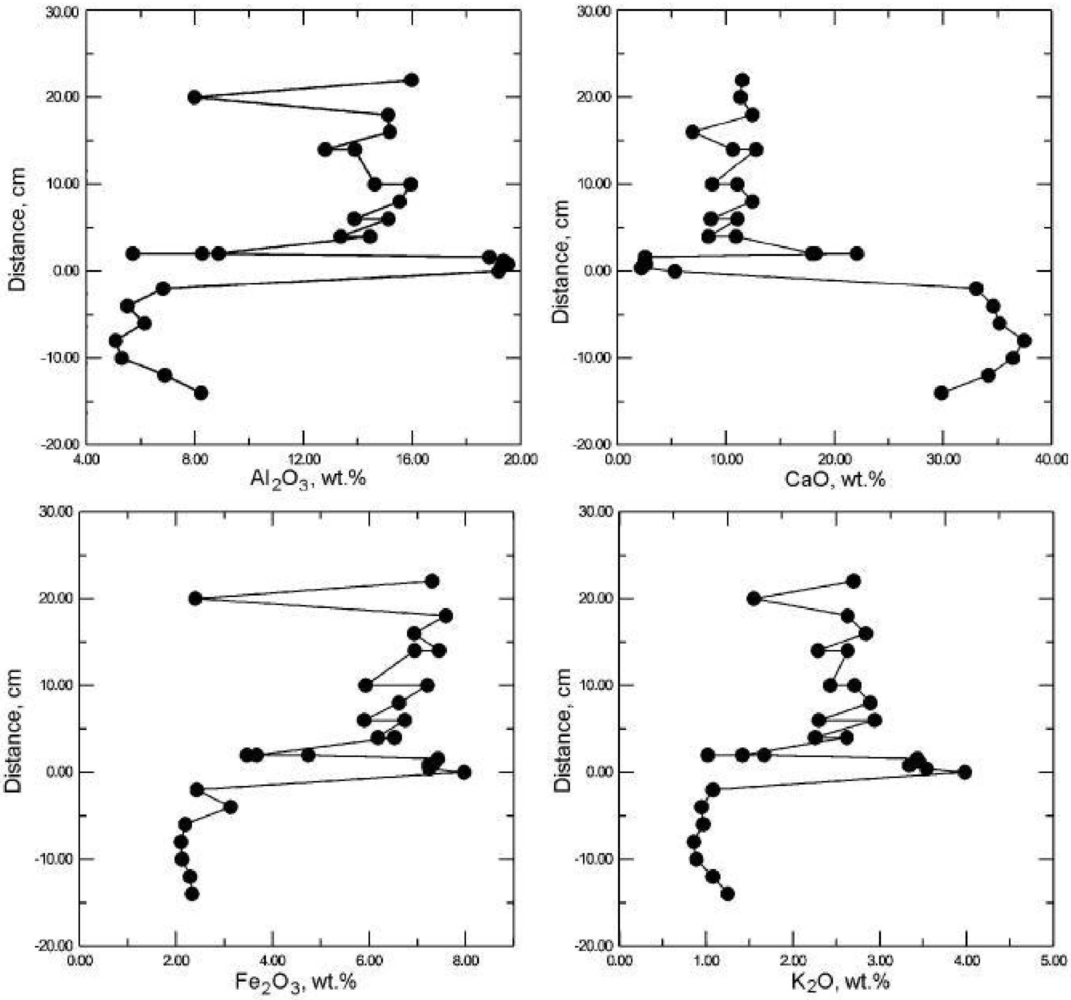


Fig. 5. Distribution of Al_2O_3, Fe_2O_3 and TiO_2 and a very low content of $CaCo_3$ in the monolith (Grachev, 2009)

Composition of the boundary layer

Compared with the underlying and overlying rocks, layer J is characterized by elevated concentrations of Al_2O_3, Fe_2O_3 and TiO_2 and a very low content of $CaCo_3$. In its lower part, the fraction of smectite equals 60% and decreases gradually upwards. The fraction of illite simultaneously increases by 20%. As subunit J1 contains notable amounts of titanomagnetite whose composition is identical to that of basalts, it is reasonable to conclude that smectite developed from volcanic material. The Ir concentration of layer J increases drastically from 5 to 9 ppm up to the barren zone (subunits J1 to J4) and than drops to 3pm in the upper third (subunits J5 to J6). The contents of As, Pb, Ag, Au and Br change synchronously. Above J4, the subunits contain nickel, iron and nickel-iron alloy similar to awaruite (Fe_3Ni) which reach a maximum at J6. The same unit contains beads of practically pure Ni and diamonds ranging in size from submicrons to tens of microns.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

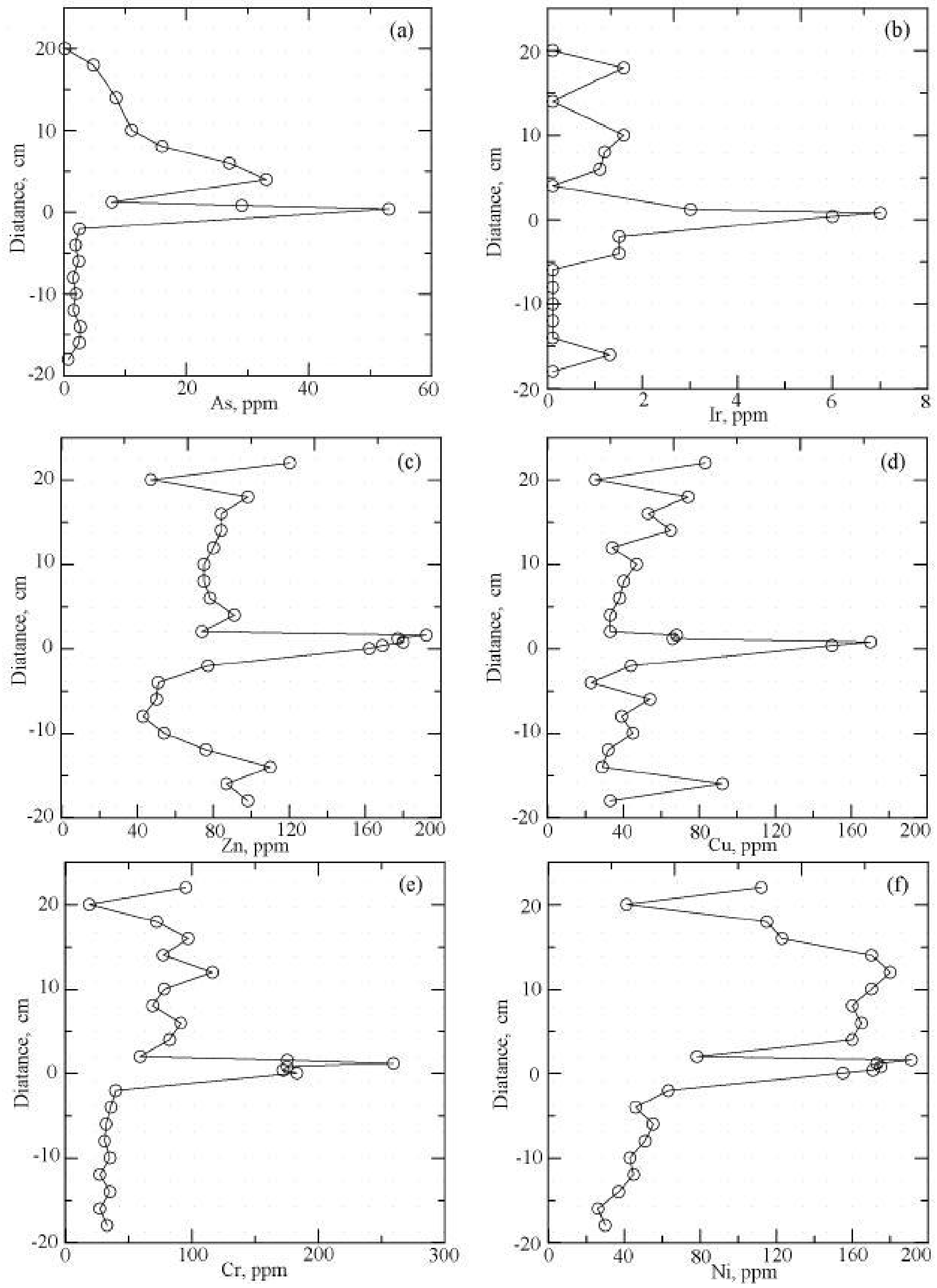


Fig. 6. The distribution of As, Ir, Zn, Cu, Cr and Ni in the monolith (Grachev, 2009)

Conclusions

The distribution of titanomagnetite, As, Pb, Ag, Au and Br in the unit J suggests a volcanic origin of the boundary layer. The subunits J5 – J6 which are characterized by nickel, iron, and an iron-nickel alloy and in J 6 also be diamond crystal were affected by the fall of an asteroid (meteorite).

The **Gams 2** site, a hitherto undescribed outcrop E of the old Haid sawmill (see Austrian Map, 1:50.000, sheet 101, Eisenerz) is a river cut on the right (north) side of the Gamsbach river, just above the alluvial flat (latitude 47°39.47´N, longitude 14°52.05´E). In this outcrop the Nierental Formation with the K/Pg boundary is exposed a a length of approximately 10 m. Besides a larger portion of the calcareous shales below the K/Pg boundary, the section is

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

comparable to the previous one. The rocks dip at 15-30° towards SW. There are subangular fragments of cross-bedded, fine-grained sandstones of 1 cm in size just above the dark brown (rusty) layer of 1-2 mm containing drop-like grains of Ni spinel (Grachev et al., 2006). A neptunian dike extends into the Maastrichtian limestone from the top towards a depth of 1 m. It´s infilling consists of clay with a high mica content. Although it has been formed before the deposition of the transitional layer, the composition of clays in virtually the same.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

STOP 2 Cretaceous/Paleogene boundary at Krautgraben/Gams

Hans EGGER & Michael WAGREICH

Topic: Cretaceous/Paleogene boundary section
Lithostratigraphic unit: Nierental Formation (Upper Gosau Subgroup)
Age: Late Maastrichtian (CC26) – early Paleocene (NP1)
Tectonic unit: Untersberg nappe / Göller nappe (Tirolicum), NCA
Location: Outcrops along a bend of Krautgraben (=upper Gamsbach) main creek
Coordinates: E 14°51'50" N 47°39'51"
Specialities: new K/Pg boundary section investigated by Grachev et al. (2008) and Egger et al. (submitted); stratigraphy, sedimentology, geochemistry and mineralogoy data.
References: Grachev et al. (2008); Egger et al. (submitted)

A second K/Pg boundary site in the Gams area is found in the Krautgraben, the valley of the Gamsbach River about 1.25 km west of the Knappengraben site (Fig. 1C). The base of the 6.5 m long section lies 2.5 m below the K/Pg boundary. Egger et al. (submitted) report first results from a combined palaeontological and geochemical analysis of that section.

The section is part of the Nierental Formation of the Gosau Group. The log of the section is given in Fig. 3. The most conspicuous feature is the ca. 2cm thick boundary clay. The base of this clay has been taken as 0 meter level in the columnar log. The sample numbers represent the centimeter distance of the sample above (+) or below (-).

The Gamsbach section consists mainly of fine-grained pelitic rocks. Below the K/Pg boundary light to medium gray marlstones and marly limestones occur (mean carbonate content of 11 samples is 54.9wt.%; mean content of total organic carbon is 0.18wt.%), which are interbedded with thin (< 15cm) sandstone turbidites (fig. 3). Dark gray mottles due bioturbation are present especially in more indurated marly limestone beds. Chondrites- and well indurated, bioturbated marly limestone with an irregular, wavy upper surface. Above this surface, 0.2 to 0.4cm of yellowish clay marks the base of the Paleocene. The yellowish clay is overlain by gray clay with a maximum carbonate content of about 13wt.% in the upper part of the layer. The overlying 200cm thick middle to dark gray marl to marlstone contains ca. 20 – 50wt.% carbonate (mean content of total organic carbon 0.23wt.%). Twelve thin (0.5 to 5cm) sandy to silty turbidite layers are intercalated in the first 9cm of this marlstone. The color of the marls and marlstones changes up-section from light to medium gray, and they are interbedded with brown to reddish layers. Turbiditic beds become thicker there (up to 14cm). A variegated marl/marlstone bed (40cm thick) occurs at 323cm. It contains clasts of red and brown marly limestone up to 15cm in diameter and some slump folds. Above this mass-flow bed, the grayish-red marl-marlstone succession extends to the top of the section, 400cm above the K/Pg boundary

The section comprises the upper part of the Cretaceous *Nephrolithus frequens* Zone (CC26) and the lower part of the Paleocene *Markalius inversus* Zone (NP1). The boundary is characterized by

(1) an enrichment of the contents of the siderophile elements Ir, Co, Ni, and Cr compared to the background and continental crustal values,
(2) a sudden decrease of carbon and oxygen isotope values,
(3) a sudden decrease of carbonate content, and
(4) an acme of the calcareous dinoflagellate cyst *Operculodinella operculata*, which is succeeded by an acme of the small coccolith species *Neobiscutum parvulum*. The *Neobiscutum* acme is associated with a positive excursion of $\delta^{18}O$ indicating a transient cooling of ocean surface waters due to short-lived changes in the configuration of ocean circulation after the impact.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

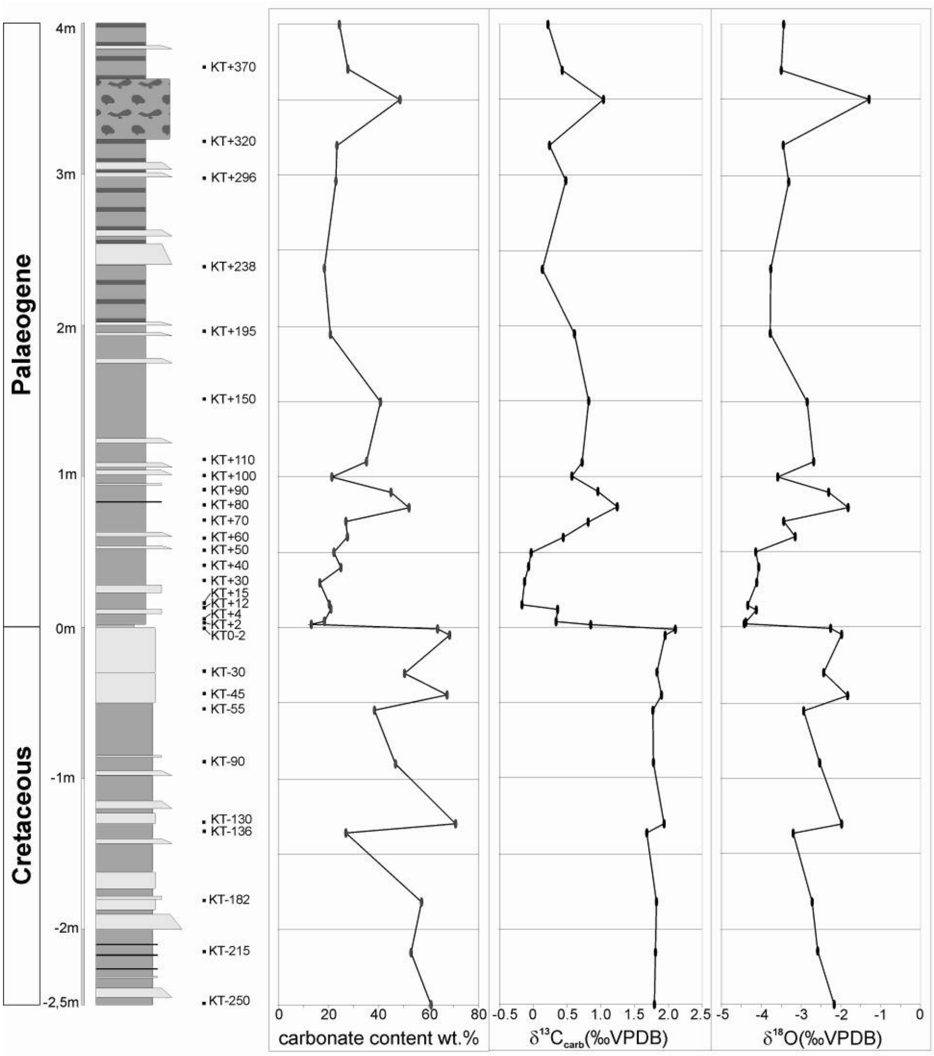


Fig. 7. Stratigraphic log of the Gamsbach section, with carbonate content and variation in the stable isotope abundances (Egger et al., submitted).

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

STOP 3 Paleocene-Eocene boundary interval in tributary of Gamsbach

Hans EGGER & Michael WAGREICH

Topic: Sedimentology, stratigraphy and isotope geochemistry of Paleocene-Eocene boundary interval
Lithostratigraphic unit: Zwieselalm Formation (Upper Gosau Subgroup)
Age: Thanetian (NP9-NP10) – Ypresian (NP10a,b,)
Tectonic unit: Unterberg nappe / Göller nappe (Tirolicum), NCA
Location: Outcrops along a southern tributary creek of Krautgraben (=upper Gamsbach), S of farm house Sommerauer
Coordinates: 014° 50' 25'' E, 47° 39' 40'' N
Specialities: high-frequency turbidites through an extended Paleocene-Eocene boundary interval
References: Egger et al. (2004, and submitted)

The Paleogene record in the studied Gams sections is not continuous but punctuated by stratigraphic gaps which comprise zone NP3 and parts of zones NP6 to NP8 (Fig. 8).The Danian deposits are characterized by a predominance of red and grey pelagic to hemipelagic marlstones and marly limestones with thin turbidites. The Selandian to lowermost Ypresian deposits exposed in the tributary creel of the Gamsnach S of Sommerauer are characterized by siliciclastic turbidites with sandstone to pelite ratios between 1:1 and 5:1. The turbidites, especially thin layers, display only weak cementation due to a very low carbonate content. Turbiditic shales are dark grey, mainly only a few centimeters thick, and largely devoid of carbonate.

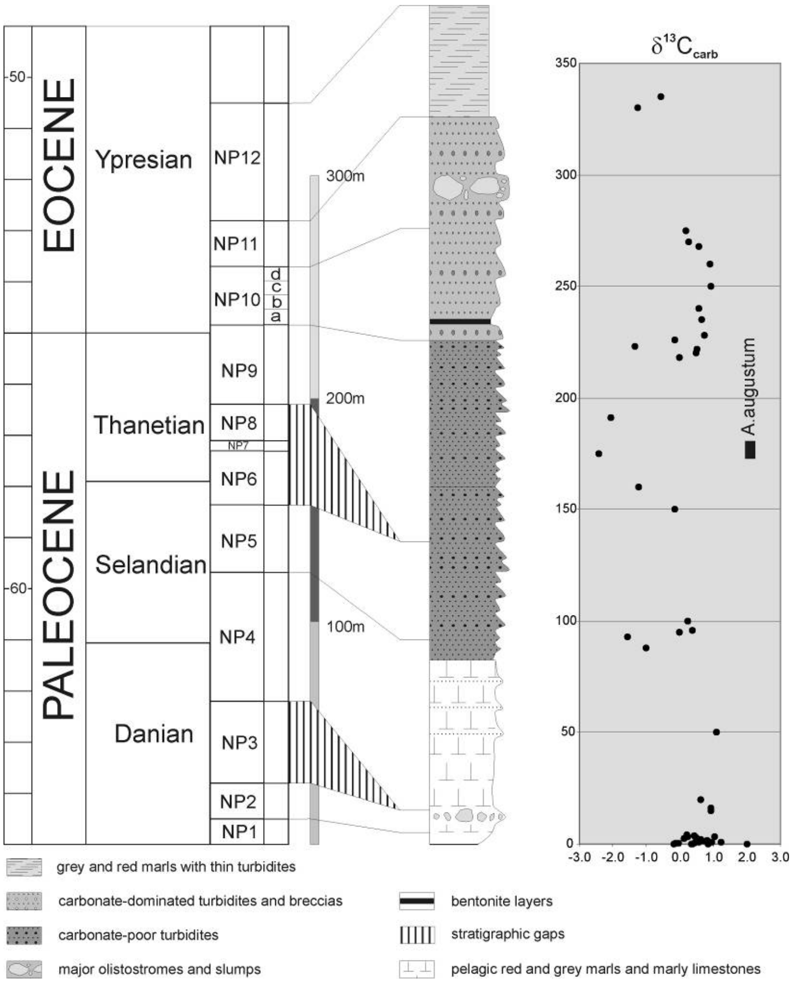


Fig. 8. Paleogene section and Paleocene/Eocene boundary interval at Gamsbach tributary.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

The basal Eocene has been recognized in a ca. 100 m thick succession of thin-bedded turbidites and alternating hemipelagic claystone and marly claystone. Occasionally, thin layers and concretions occur consisting essentially of early diagenetic siderite. The succession is characterized by a negative excursion of carbon isotope values, the occurrence of the dinoflagellate species *Apectodinium augustum* and the first occurrence of the calcareous nannoplankton genus *Rhomboaster*.
The largely carbonate-free turbiditic succession of the Paleocene/Eocene-transition grades into a succession dominated by carbonate turbidites (NP10 to NP11). Within the lower part of this succession (sub-zone NP10a) four 3 to 9 cm thick montmorillonite layers were discovered, which are interpreted as volcanic ashes. Similar layers have been found in other Austrian sections and were correlated with ashes of the Fur Formation in northern Denmark. The wide dispersal distance of the tephras implies Plinian scale eruptions and multiple ejections of large volumes of pyroclastic material.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

STOP 4 Mid-Maastrichtian ammonite site E of Haid

Herbert SUMMESBERGER, Michael WAGREICH & Gerhard BRYDA

Topic: Sedimentology and integrated stratigraphy in mid-Maastrichtian deposits
Lithostratigraphic unit: Nierental Formation (Upper Gosau Subgroup)
Age: upper part of *Gansserina gansseri* Zone, CC25b/ UC20a^{TP}
Tectonic unit: Untersberg nappe / Göller nappe (Tirolicum), NCA
Location: Outcrops along a forest road and creek northeast of Haid
Coordinates: 14° 51' 35'' E, 47° 40' 00'' N
Specialities: high-frequency turbidites through the Paleocene-Eocene boundary interval
References: Summesberger et al. (2009)

The investigated outcrop within the Nierental Formation exposes about 5 metres of thin and evenly bedded sandy/silty grey shales and marls with a few intercalations of coarse sandstones below 10 cm thickness. The beds are a few centimetres thick, the bedding planes are more or less even. Some bedding planes are coated by a rusty cover. Bioturbation is common, especially in the lower part of the outcrop. *Chondrites* is a typical trace fossil present at topmost parts of graded sandstone/ siltstone turbidite beds. Some bedding planes also show grazing traces by echinoids. Pelitic beds can be subdivided into soft sandy turbiditic shales and more indurated marls, which are interpreted as hemipelagic. The stratigraphic position of the cephalopod-bearing grey marl bed is below a 16 cm thick graded sandstone layer and thus is also interpreted as a hemipelagic, non-turbiditic layer.

Nannoplankton

The most important marker species recognized in the six samples is *Lithraphidites quadratus.* This species is rare to very rare (1 specimen in around 100 fields of view). The presence of *L. quadratus* in all the samples and the absence of *Micula murus* and *Nephrolithus frequens* allow the recognition of standard nannplankton zones CC25b (according to Sissingh, 1977; Perch-Nielsen, 1985) and UC20a^{TP} (Burnett, 1998). The presence of *Corollithion completum* further corroborates this assignement according to Burnett (1998). An early Late Maastrichtian age is interpreted in correlation to belemnite zonations (*tegulatus /junior* Subzone or younger; Burnett, 1998). Very rarely, Campanian to Lower Maastrichtian taxa such as *Broinsonia* and *Quadrum* are found, which are interpreted as reworked from older strata.

Planktonic Foraminifer

All 3 samples contain a similar foraminifera assemblage, mainly characterized by high amounts (>90 %) of planktic foraminifera. The most characteristic and stratigraphically important taxa present are: *Globotruncanita stuarti; Rosita contusa, Abathomphalus intermedius, Racemiguembelina intermedia.*
Globotruncanita stuarti and *Rosita contusa* are typical Maastrichtian species. *Abathomphalus intermedius* and *Racemiguembelina intermedia* both have a first occurrence higher up in the Maastrichtian, within the *Gansserina gansseri* Zone (Robaszynski & Caron, 1995). According to Robaszynski & Caron (1995) *Racemiguembelina fructicosa* occurs below the *Abathomphalus mayaroensis* Zone*.*
Thus, the samples can be attributed to the upper part of the *Gansserina gansseri* Zone, the *Contusotruncana contusa* (Sub-) Zone, within the upper part of the of the *Gansserina gansseri* Zone, just below the first occurrence of *Abathomphalus mayaroensis*. According to LI et al. (1999, 2000), based on data from El Kef/Tunisia, the assemblage with *Racemiguembelina* (*Pseudotextularia*) *intermedia and Rosita contusa* defines planktic zone CF5 (*Pseudotextularia intermedia* Zone).

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

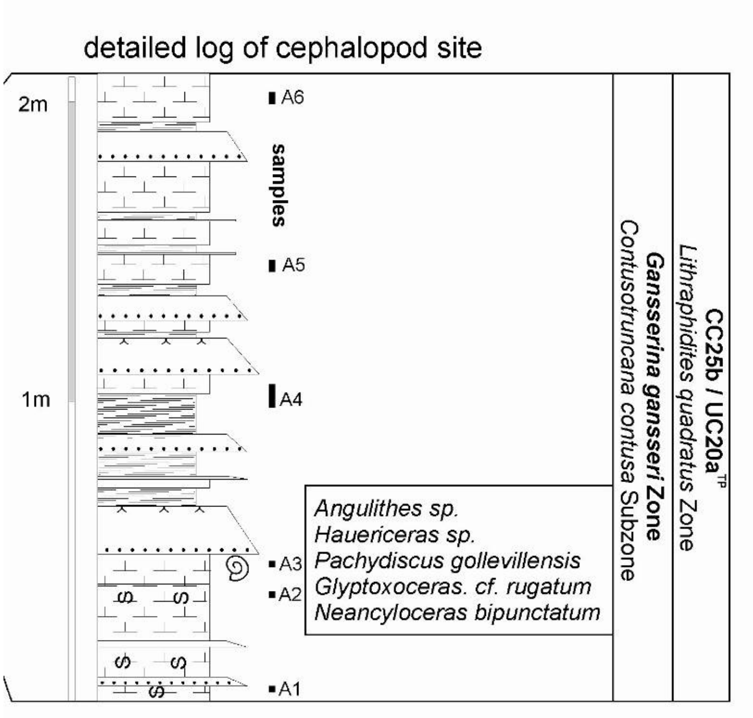


Fig. 9. Section of Stop 4 east of Haid (Summesberger et al., 2009).

Cephalopods and chronostratigraphic correlation

The most indicative ammonite taxon present is *Pachydiscus* (*P.*) *gollevillensis* (D'ORBIGNY, 1850), which ranges at Zumaya (Spain) from the upper part of the *Gansseri* Zone to the middle *Mayaroensis* Zone (Ward & Kennedy, 1993). In terms of ammonite zones this corresponds to the *Anapachydiscus fresvillensis* Zone, which is upper Lower Maastrichtian to lower Upper Maastrichtian. The L.O. level of *P.* (*P.*) *gollevillensis* at Zumaya is within the Upper Maastrichtian zones of *Anapachydiscus fresvillensis* and *Abathophalus mayaroensis* (Ward & Kennedy, 1993: fig. 5), and above the F.O. of *Lithraphidites quadratus* in the Biscay region (Burnett, et al. 1992), within nannofossil zone UC20 (Burnett, 1998). At Sopelana I (Spain) *P. gollevillensis* occurs about 50 m below the K/P boundary near the base of the *Mayaroensis* Zone (Ward & Kennedy, 1993), at Sopelana II (Spain; Ward & Kennedy 1993) it occurs about 50 m below K/P in the *Gansseri* Zone, at Hendaye (France, loc.cit., fig. 8) it ranges within the topmost Maastrichtian Zone of *Anapachydiscus terminus*. Its extinction level is about 10 m below K/P. At Bidart II (France, loc.cit., fig. 11) it occurs in the *Mayaroensis* Zone. Taken together all informations from the Bay of Biscay *P. gollevillensis* is mainly an Upper Maastrichtian species, appearing at the top of the upper Lower Maastrichtian *Gansseri* Zone.

Combining nannofossil (CC25b/UC20a^{TP}) and planktic foraminiferal data (upper part of *Gansserina gansseri* Zone, *Contusotruncana contusa* (Sub-) Zone, CF5 of Li et al., 1999; below the first occurrence of *Abathomphalus mayaroensis*) gives a more precise stratigraphic frame for the cephalopod fauna and allows correlation to other zonations, e.g. the boreal belemnite zonation of northern Europe. The first occurrence of *Lithraphidites quadratus* was recognized within the *Belemnitella junior* Zone of NW Germany, i.e. within the *tegulatus/junior* Subzone, the lowermost subzone of the Upper Maastrichtian. According to the absence of the nannofossil *Micula murus* in our samples, the age cannot be younger than the top of the *Belemnitella junior* Zone. Integrating foraminiferal data, especially the lack of *Abathomphalus mayaroensis*, leads to a correlation of the investigated cephalopod horizon with the interval from the base of the *Spyridoceramus tegulatus /Belemnitella junior* Subzone to the lower part of the *Tenuipteria argentea /Belemnitella junior* Subzone (Burnett, 1998 and TSCreator, www.stratigraphy.org).

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

RECCCE Excursion Day 2, Tuesday, April 28, 2009

STOP 5 Cenomanian-Turonian at Rehkogelgraben/Hagenmühle (Upper Austria)

Michael WAGREICH, Stephanie NEUHUBER & Hans EGGER

Topic: hemipelagic sediments, black shales and the Cenomanian-Turonian transition, CORBs
Lithostratigraphic unit: “Buntmergelserie” (Upper Gosau Subgroup)
Age: upper part of *Gansserina gansseri* Zone, CC25b/ UC20a^{TP}
Tectonic unit: Ultrahelvetic unit
Location: Outcrops in Rehkogelgraben creek
Coordinates: 013° 55’ 30” E, 47° 56’ 08” N
Specialities: black shales below water table (use rubber boots) and cyclicity including CORBs
References: Rögl in Kollmann & Summesberger (1982), Wagreich et al. (2008)

The Ultrahelvetic units of Austria are remnants of the European continental slope, lying between the Helvetic shelf in the north and the abyssal Rhenodanubian/Penninic Flysch basins, a part of the Alpine Tethys. The Rehkogelgraben section (Kollmann & Summesberger, 1982) belongs to an Ultrahelvetic slice within the Rhenodanubian Flysch Zone between Hagenmühle and Greisenbach, to the east of Gmunden (Upper Austria, Figure 10). The investigated Cenomanian-Turonian boundary section includes distinctive black shale horizons and a transition from black shales into marly limestones and red marls, which are typical for Ultrahelvetic sections in Upper Austria (Fig. 11). Strata within these tectonic windows have been traditionally attributed to the “Buntmergelserie”, an informal lithostratigraphic unit comprising Aptian/Albian to Eocene pelagic and hemipelagic shales, marlstones, and marly limestones with rhythmic limestone and marl alterations. Upper to middle bathyal water depths have been inferred for the Ultrahelvetic units.

The section comprises a 5 m thick succession of Upper Cenomanian marl-limestone cycles overlain by a black shale interval composed of three black shale layers and carbonate-free claystones, followed by Lower Turonian white to light grey marly limestones with thin marl layers (Fig. 12). The main biostratigraphic events in the section are the last occurrence of *Rotalipora* and the first occurrences of the planktic foraminifer *Helvetoglobotruncana helvetica* and the nannofossil *Quadrum gartneri*. The thickest black shale horizon has a TOC content of about 5%, with predominantly marine organic matter of kerogen type II. Vitrinite reflectance and Rock-Eval parameter T_{max} (< 424°C) indicate low maturity. HI values range from 261 to 362 mg HC/g TOC. $\delta^{13}C$ values of bulk rock carbonates display the well documented positive shift around the black shale interval, allowing correlation of the Rehkogelgraben section with other sections such as the Global Boundary Stratotype Section and Point (GSSP) succession at Pueblo, USA. In the lower part of the section, values lie uniformly around 2.5 ‰ and show a slight decrease before the first small peak of 2.6 ‰, which is associated with the LO of the nannofossils *Lithraphidites acutus.* The first occurrence of the nannofossil *Eprolithus octopetalus*, above black shale 2, is associated with a second carbon isotope peak of up to 3.4 ‰, followed by a small peak below 3 ‰ immediately after last the increase in TOC, succeed by a final peak of 3 ‰. Towards the top of the section, values progressively decrease down to 2.7 ‰, but never reach values as low as in the Upper Cenomanian. Sedimentation rates at Rehkogelgraben (average 2.5 mm/ka) are significantly lower than those at Pueblo.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

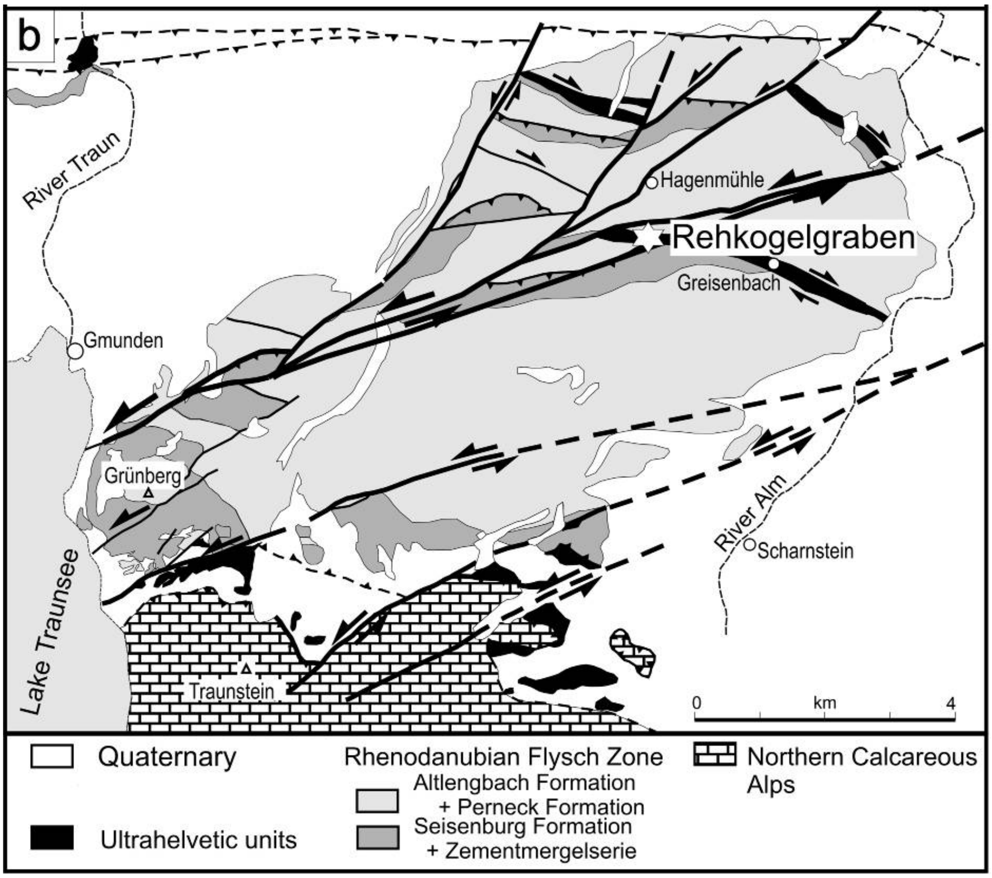


Fig. 10. Geological sketch map of the area east of Gmunden, including outcrop Rehkogelgraben.

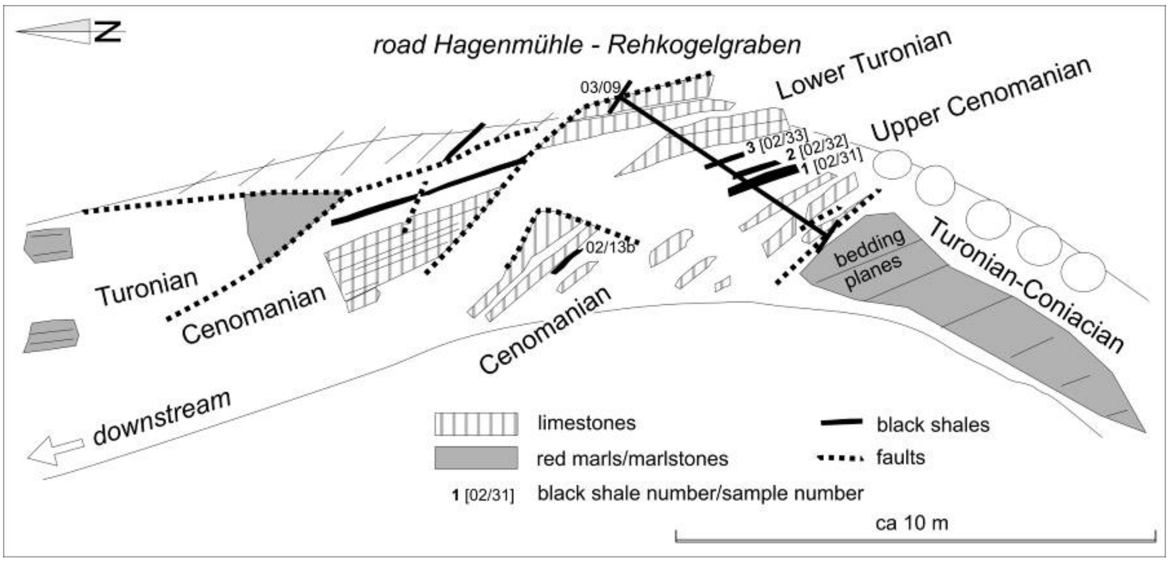


Fig. 11. Map view sketch of the Cenomanian-Turonian outcrop in the creek Rehkogelgraben.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

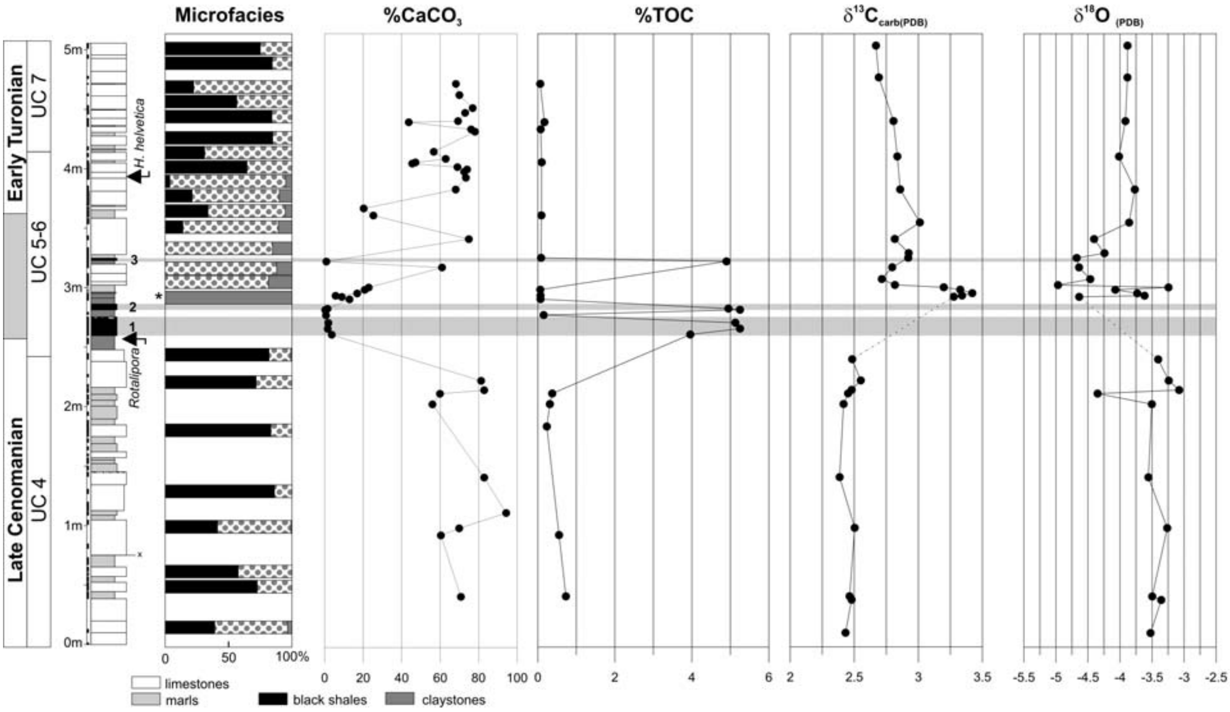


Fig. 12. Sedimentological log of the Rehkogelgraben Cenomanian-Turonian section, including microfacies data based on counts of planktonic foraminifera (black), calcispheres (stippled) and radiolaria (grey) in selected thin sections (except sample marked with * which is a washed residue from a radiolaria-bearing claystone), carbonate and TOC contents, carbon and oxygen isotope values (Wagreich et al., 2008).

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

STOP 6 Paleocene-Eocene at Anthering near Salzburg

Hans EGGER

Topic: Paleocene/Eocene-boundary section in a succession of deep-water turbidites and hemipelagites
Lithostratigraphic unit: Rhenodanubian Group, Anthering Formation
Age: upper part of calcareous nannoplankton Zone NP9 to upper part of NP10
Tectonic unit: Rhenodanubian Flysch Zone
Location: Outcrops in the Kohlbachgraben near Anthering
Coordinates: E 13° 01’ 17’’, N 47° 53’ 19’’
Specialities: carbon isotope event, *Apectodinium* acme, Lower Eocene bentonites
References: Heilmann-Clausen & Egger, 1997, Egger, Heilmann-Clausen & Schmitz (2000), Crouch et al. (2001), Egger et al. (2003), Huber et al. (2003), Egger & Brückl (2006), Egger, Heilmann-Clausen &Schmitz (2009),

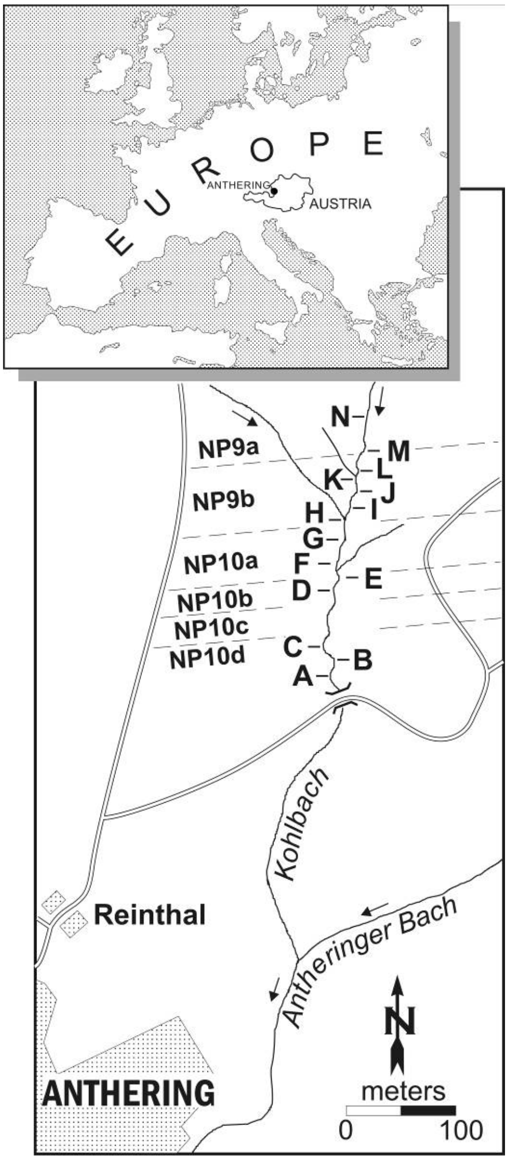


Fig.13. Location of the Anthering section (A-N … outcrops)

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

The 250 m thick Anthering section (Fig. 13) contains deposits from calcareous nannoplankton zones NP9 and NP10 and displays the global negative carbon isotope excursion (CIE) and the acme of the dinoflagellate genus *Apectodinium* in the upper part of zone NP9. The outcrop across the CIE displays a two-fold lithological subvision (Fig. 14).

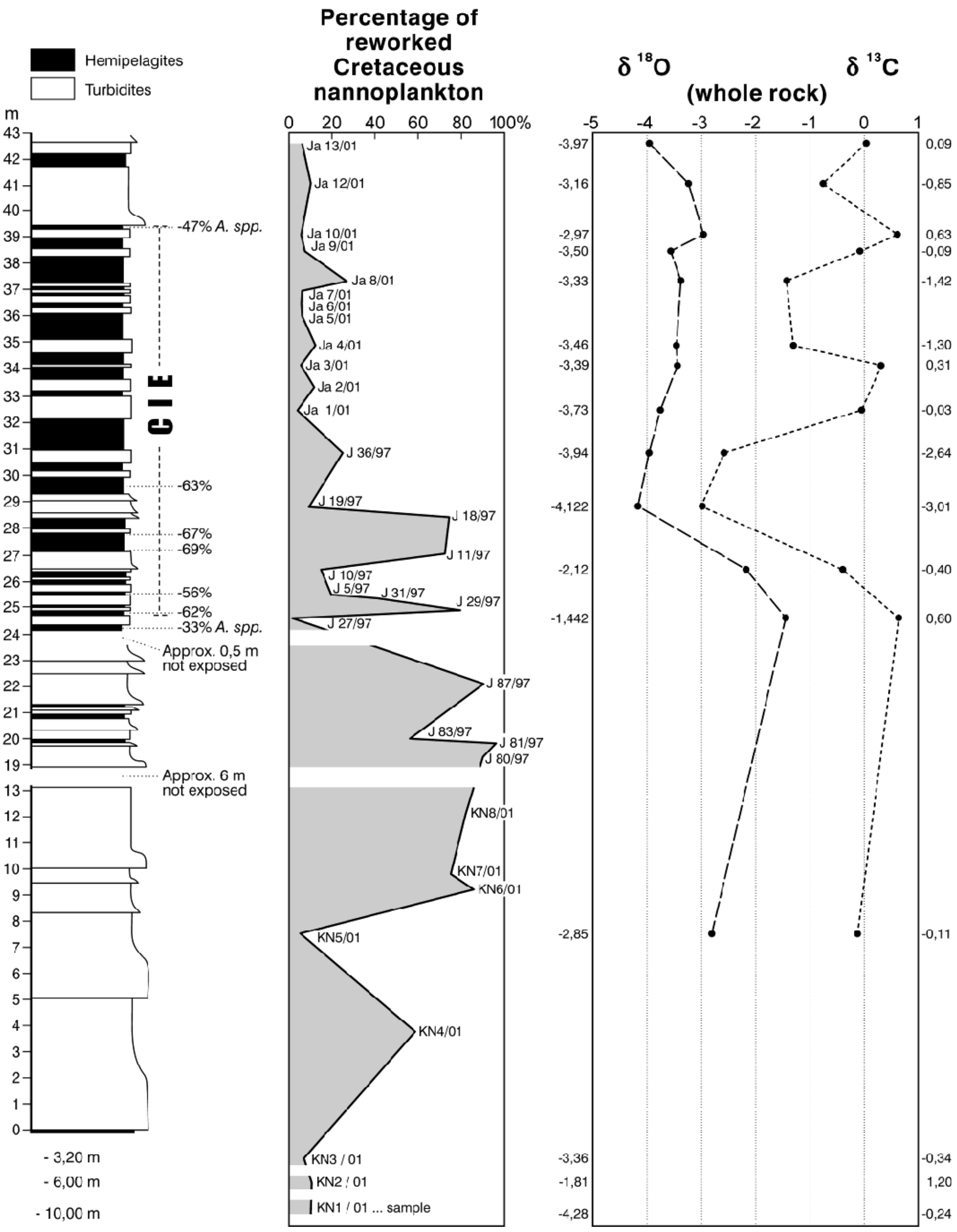


Fig. 14. Lithostratigraphy, percentages of redeposited Cretaceous nannoplankton and stable isotope record of oxygen and carbon across the CIE-interval at Anthering (A. spp…...percentages of the genus *Apectodinium* in the dinoflagellate assemblages).

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Below the CIE, the section consists primarily of turbidites (98 %) with bed-thicknesses between 0.1 m and 5 m and an average thickness of 1.08 m. The thicker beds show graded bedding with sand-sized fractions at the base. Altogether, sandstone makes up 29 % of the succession. This is an unusually high percentage, as this fraction counts for only 5 % in the entire Anthering section. Small isolated outcrops below the base of the measured section indicate that the onset of this thick-bedded facies is abrupt, without any transition to the underlying thinner-bedded facies. The turbidite facies displays a thinning and fining upward trend and a gradual transition into a clay-rich facies which dominates the upper part of the outcrop.

The carbon isotope and dinoflagellate data suggest that the CIE-interval at Anthering attains a thickness of 15 m, comprising turbidites and hemipelagites (Fig. 14). The thickness of the turbidites varies between 0.08 m and 2.25 m, although only the thickest layer exceeds 1 m thickness. The average thickness of the turbidite beds is 0.39 m and sand-grade material, which makes up 2 % of this facies, occurs only in the thickest layers. Excluding the turbidites the remaining thickness of hemipelagic claystone is 8.4 m. Using Fe– and Ca–intensity curves which probably represent precessional cycles, Röhl et al. (2000) calculated that the CIE interval lasted for 170 ky. From this, a hemipelagic sedimentation rate of 49 mmky^{-1} has been calculated for the compacted sediment across the CIE.

This CIE-interval sedimentation rate is unusual high compared to the mean sedimentation rate of the Rhenodanubian Group, estimated at 25 mmky^{-1} (Egger & Schwerd, 2008). This value incorporates both turbidites and hemipelagites. The rate of hemipelagic sedimentation in the Paleocene can also be calculated using the Strubach Tonstein, which was deposited during a period of ca. 5 my between the upper part of calcareous nannoplankton zone NP3 and the lower part of zone NP8 (Egger et al., 2002). About 25 % of this 50 m thick lithostratigraphic unit consists of turbidites. Excluding the turbidites, the rate of hemipelagic sedimentation has been calculated as 8 mmky^{-1}. Similar values (7 - 9 mm ky^{-1}) were determined for the middle and upper part of Zone NP10, whereas a hemipelagic accumulation rate of 13 mmky^{-1} was calculated for the lower part of this zone (Egger et al., 2003). Thus, the CIE was associated with a six-fold increase in the siliciclastic hemipelagite sedimentation rate in the Penninic Basin.

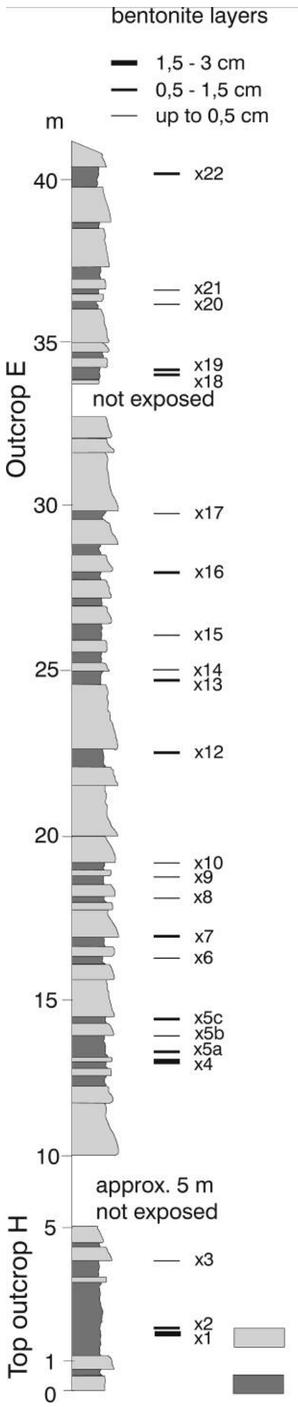
Enhanced erosion of land areas around the CIE-interval can also be inferred from the composition of calcareous nannoplankton assemblages. Whereas, in general, reworked Cretaceous species form only 2-3 % of the calcareous nannoplankton assemblages of the Anthering section, substantial Cretaceous admixtures are present in many samples from across the CIE (Fig. 2). The oldest nannoplankton assemblage showing a high percentage (>50 %) of reworked specimens originates from a turbidite bed 22 m below the onset of the CIE. Three metres above the onset of this geochemical marker, the youngest assemblage with a similar percentage of reworked Cretaceous specimens has been found.

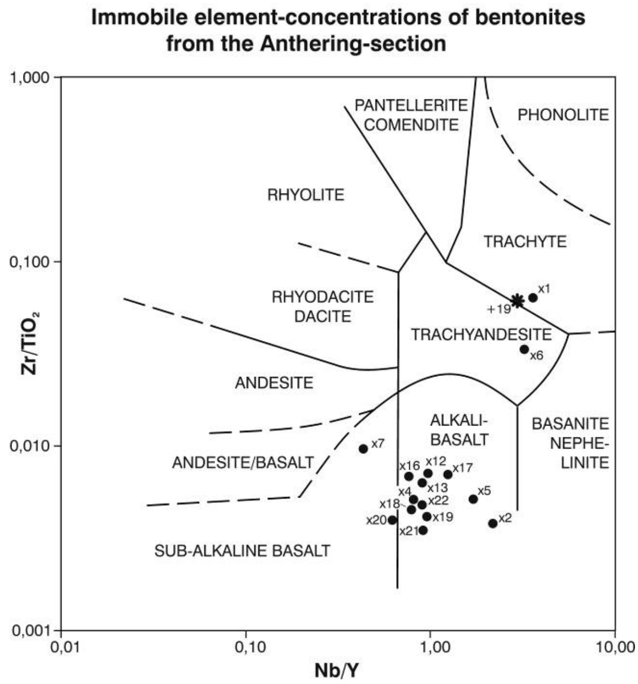
Most of the reworked specimens consist of species with long stratigraphic ranges (*Watznaueria barnesae*, *Micula staurophora*, *Retecapsa crenulata*, *Cribrosphaerella ehrenbergii*, *Eiffellithus turriseiffelii*). Biostratigraphically important species that were found in all of the counted samples include *Broinsonia parca*, *Arkhangelskiella cymbiformis* (small specimens), *Calculites obscurus*, *Lucianorhabdus cayeuxii* and *Eiffellithus eximius* whilst *Marthasterites furcatus*, *Eprolithus floralis* and *Lithastrinus grillii* were found only occasionally. This assemblage suggests that predominantly lower to middle Campanian deposits were reworked at the end of the Paleocene. The reworked Campanian nannoflora in the Penninic Basin primarily originates from the inner shelf of the European Plate, whereas the southerly Helvetic unit of the outer shelf displays a stratigraphically much more complete sedimentary record in the Upper Cretaceous and across the Cretaceous/Paleogene boundary.

In the lowermost Eocene (Subzone NP10a) at the Anthering section, 23 layers of altered volcanic ash (bentonites) originating from the North Atlantic Igneous Province have been

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

recorded, about 1,900 km away from the source area (Fig. 15). The Austrian bentonites are distal equivalents of the “main ash-phase” in Denmark and the North Sea basin. Egger & Brückl (2006) have calculated the total eruption volume of this series as 21,000 km^3, which occurred in 600,000 years. The most powerful single eruption of this series took place 54.0 million years ago (Ma) and ejected ca. 1,200 km^3 of ash material which makes it one of the largest basaltic pyroclastic eruptions in geological history. The clustering of eruptions must have significantly affected the incoming solar radiation in the early Eocene by the continuous production of stratospheric dust and aerosol clouds. This hypothesis is corroborated by oxygen isotope values which indicate a global decrease of sea surface temperatures between 1–2°C during this major phase of explosive volcanism.





Sample (ppm)	Nb	Zr	Y	TiO_2
x1	146.0	486.0	40.0	7673
x2	33.0	244.0	15.0	63887
x4	28.0	238.0	36.0	46700
x5a	40.0	225.0	22.0	49700
x6	154.0	490.0	45.0	14000
x7	26.0	615.0	60.0	37000
x12	27.0	254.0	28.0	35696
x13	31.0	213.0	33.0	34028
x16	30.0	222.0	39.0	32360
x17	28.0	225.0	22.0	31786
x18	36.1	258.4	44.4	34432
x19	33.8	254.4	34.5	34342
x20	33.6	252.8	51.9	39103
x21	29.9	218.8	32.8	37819
x22	35.1	308.0	40.0	39954
+19(Fur)	121.0	684.0	42.0	11300

Fig. 15. Immobile element concentrations of the bentonites at Anthering.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

References

Burnett, J.A. (1998): Upper Cretaceous. In: Bown, P.R. (ed.): Calcareous Nannofossil Biostratigraphy: 132-199. Cambridge (Chapman & Hall).

Burnett, J.A., Kennedy, W.J. & Ward, P.D. (1992): Maastrichtian nannofossil biostratigraphy in the Biscay region (south-western France, northern Spain). Newsletters on Stratigraphy **26**, 145-155.

Crouch, E.M., Heilmann-Clausen, C., Brinkhuis, H., Morgans, H.E.G., Rogers, K.M., Egger, H. & Schmitz, B. (2001): Global dinoflagellate event associated with the late Paleocene thermal maximum. Geology **29**, 315-318.

Egger, H., Heilmann-Clausen, C. & Schmitz, B. (2000): The Palaeocene/Eocene-boundary interval of a Tethyan deep-sea section and its correlation with the North Sea Basin. Société Géologique de France Bulletin **171**, 207-216.

Egger, H., Homayoun, M. & Schnabel, W (2002): Tectonic and climatic control of Paleogene sedimentation in the Rhenodanubian Flysch Basin (Eastern Alps, Austria). Sedimentary Geology **152**, 147-162.

Egger, H., Fenner, J., Heilmann-Clausen, C., Rögl, F., Sachsenhofer, R.F. & Schmitz, B. (2003): Paleoproductivity of the northwestern Tethyan margin (Anthering section, Austria) across the Paleocene-Eocene transition. Geological Society of America Special Paper **369**, 133-146.

Egger, H. & Brückl, E. (2006): Gigantic volcanic eruptions and climatic change in the early Eocene. International Journal of Earth Sciences **95**, 1065-1070.

Egger, H. & Schwerd, K. (2008): Stratigraphy and sedimentation rates of Upper Cretaceous deep-water systems of the Rhenodanubian Group (Eastern Alps, Germany). Cretaceous Research **29**, 405-416.

Egger, H., Heilmann-Clausen, C. & Schmitz, B. (2009): From shelf to abyss: Record of the Paleocene/Eocene-boundary in the Eastern Alps (Austria). Geologica Acta **7**, 215-227.

Egger, H., Rögl, F., Wagreich, M. (2004): Biostratigraphy and facies of Paleogene deep-water deposits at Gams (Gosau Group, Austria). Annalen des Naturhistorischen Museums Wien, Serie A, **106A**, 291-307.

Egger, H. & Wagreich, M. (2001): Upper Paleocene - Lower Eocene nannofossils from the Gosau Group of Gams/Styria (Austria). In: Piller, W.E. & Rasser, M.W. (eds): Paleogene of the Eastern Alps.- Österreichische Akademie der Wissenschaften, Schriftenreihe der Erdwissenschaftlichen Kommissionen, 14, 465-472.

Grachev, A. F., Korchagin, O. A., Kollmann, H. A., Pechersky, D. M. & Tsel´movich, A. A. (2005): A new look at the nature of the transitional layer at the K/T boundary near Gams, Eastern Alps, Austria, and the problem of the mass extinction of the biota. Russian Jounal of Earth Sciences **7**, 1-45.

Grachev, A. F., Korchagin, O. A., Kollmann, H. A., Pechersky, D. M. & Tsel´movich, A. A. (2006): Two Spinel Populations from the Cretaceous/Paleogene (K/T) Boundary Clay Layer in the Gams Stratigraphic Sequence, Eastern Alps. Russian Journal of Earth Sciences **9**, 1-11.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Grachev, A.F., Kamensky, I.L., Korchagin, O.A. & Kollmann, H.A. (2007): The first data on helium isotopy in a transitional clay layer at the Cretaceous-Paleogene boundary (Gams, Eastern Alps). Physics of the Solid Earth **43**, 766-772.

Grachev, A.F., Korchagin, O.A., Tselmovich, V.A. & Kollmann, H.A. (2008): Cosmic dust and micrometeorites in the transitional clay layer at the Cretaceous-Paleogene boundary in the Gams Section. Physics of the Solid Earth **44**, 555-569.

Grachev, A.F. (ed.) (2009): The K/T boundary of Gams (Eastern Alps, Austria) and the nature of terminal Cretaceous mass extinction. Vienna (Geologische Bundesanstalt), 199 p.

Heilmann-Clausen, C. & Egger, H. (1997): An ash-bearing Paleocene/Eocene sequence at Anthering, Austria: biostratigraphical correlation with the North Sea Basin. Danmarks og Grønlands undersøgelse rapport, 1997/87, 13.

Herm, D., Von Hillebrandt, A. & Perch-Nielsen, K. (1981): Die Kreide/Tertiärgrenze im Lattengebirge (Nördliche Kalkalpen) in mikropaläontologischer Sicht. In: Hagn, H. (ed.): Die Bayerischen Alpen und ihr Vorland in mikropaläontologischer Sicht. Geologica Bavarica **82**, 319-344.

Huber, H., Koeberl, C. & Egger, H. (2003): Geochemical study of Lower Eocene volcanic ash layers from the Alpine Anthering Formation, Austria. Geochemical Journal **37**, 123-134.

Keller, G. (1988): Extinction, survioship and evolution of planktonic foraminifera across the Cretaceous/Tertiary boundary at El-Kef, Tunisia. Mar. Micropaleontol. **13**, 239-263.

Kollmann, H.A. (1964): Stratigraphie und Tektonik des Gosaubeckens von Gams (Steiermark, Österreich).- Jahrbuch der Geologischen Bundesanstalt **107**, 189-212.

Kollmann, H.A. & Sachsenhofer, R. F. (1998): Zur Genese des Gagats von Gams bei Hieflau (Oberkreide, Steiermark). Mitteilungen des Referats Geologie und Paläontologie am Landesmuseum Joanneum, Sonderheft **2**, 223-238.

Kollmann, H. A. & Summesberger, H. (1982): Excursions to Coniacian - Maastrichtian Stages in the Austrian Alps. 4. Meeting, Working Group Coniacian - Maastrichtian Stage: 1-105, Vienna.

Lahodynsky, R. (1988a): Geology of the K/T boundary site at Knappengraben creek (Gams, Styria).- IGCP Project 199 “Rare events in geology”; Abstracts. Berichte der Geologischen Bundesanstalt, **15**: 33-36.

Lahodynsky, R. (1988b): Lithostratigraphy and sedimentology across the Cretaceous/Tertiary Boundary in the Flyschgosau (Eastern Alps, Austria). Revista Espanola Paleont., spec. vol. 1988, 73-82.

Li, L., Keller, G. & Stinnesbeck, W. (1999): The Late Campanian and Maastrichtian in northwestern Tunisia: Paleoenvironmental inferences from lithology, macrofauna and benthic foraminifera. - Cretaceous Research **20**, 231-252.

Li, L., Keller, G., Adatte, T. & Stinnesbeck, W. (2000): Late Cretaceous sea level changes in Tunisia: a multi-disciplinary approach. Journal of the Geological Society of London **157**, 447- 458.

Perch-Nielsen, K. (1985): Mesozoic calcareous nannofossils. In: Bolli, H.M., Saunders, J.B. & Perch-Nielsen, K. (eds).- Plankton Stratigraphy: 329-426, Cambridge (Cambridge University Press).

Peryt, D., Lahodynsky, R., Rocchia, R. & Boclet, D. (1993) : The Cretaceous/Paleogene boundary and planktonic foraminifera in the Flyschgosau (Eastern Alps, Austria). Palaeogeography, Palaeoclimatology, Palaeoecology **104**:239-252.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Pueyo, E.L., Mauritsch, H.J., Gawlick, H.-J., Scholger, R. & Frisch, W. (2007): New evidence for block and thrust sheet rotations in the central northern Calcareous Alps deduced from two pervasive remagnetization events. Tectonics **26**:TC5011, doi:10.1029/2006TC001965.

Robaszyński, F. & Caron, M. (1995): Foraminifères planctoniques du Crétacé: commentaire de la zonation Europe-Méditerranée. Bulletin de la Société Géologique de France **6**: 681-692.

Röhl, U., Bralower, T.J., Norris, R.D., Wefer, G. (2000): New chronology for the late Palaeocene thermal maximum and its environmental implications. Geology, **28**, 927–930.

Siegl-Farkas, A. & Wagreich, M. (1997): Correlation of palyno- (spores, pollen, dinoflagellates) and calcareous nannofossil zones in the Late Cretaceous of the Northern Calcareous Alps (Austria) and Transdanubian Central Range (Hungary). - Geological Survey of Hungary (Budapest): Advances in Austrian-Hungarian Joint Geological Research: 127-135.

Sissingh, W. (1977): Biostratigraphy of Cretaceous nannoplankton. - Geologie en Mijnbow **57**, 433-440.

Stradner, H. & Rögl, F. (1988): Microfauna and nannoflora of the Knappengraben section (Austria) across the Cretaceous/Tertiary boundary.- IGCP Project 199 "Rare events in geology"; Abstracts. Berichte der Geologischen Bundesanstalt **15**, 25-26.

Summesberger, H. & Kennedy, W.J. (1996): Turonian Ammonites from the Gosau Group (Upper Cretaceous; Northern Calcareous Alps; Austria) with a revision of *Barroisiceras haberfellneri* (HAUER 1866). Beiträge zur Paläontologie **21**, 1-75.

Summesberger, H., Wagreich, M. & Bryda, G. (2009): Upper Maastrichtian cephalopods and the correlation to calcareous nannoplankton and planktic foraminifera zones in the Gams Basin (Gosau Group; Styria, Austria). Annalen des Naturhistorischen Museums Wien **111A**, 159–182.

Summesberger, H., Wagreich, M., Tröger, K.-A. & Jagt, J. W.M. (1999): Integrated biostratigraphy of the Santonian/Campanian Gosau Group of the Gams Area (Late Cretaceous; Styria, Austria). Beiträge zur Paläontologie **24**, 155-205.

Wagreich, M. (1993): Subcrustal tectonic erosion in orogenic belts - A model for the Late Cretaceous subsidence of the Northern Calcareous Alps (Austria). Geology **21**, 941-944.

Wagreich, M. (1995): Subduction tectonic erosion and Late Cretaceous subsidence along the northern Austroalpine margin (Eastern Alps, Austria). Tectonophysics **242**, 63-78.

Wagreich, M. (2004): Biostratigraphy and lithostratigraphy of the Krimpenbach Formation (Upper Santonian - Campanian), Gosau Group of Gams (Austria). Annalen des Naturhistorischen Museums Wien, Serie A **106**, 123-138.

Wagreich, M., Bojar, A.-V., Sachsenhofer, R.F., Neuhuber, S. & Egger, H. (2008): Calcareous nannoplankton, planktonic foraminiferal and carbonate carbon isotope stratigraphy of the Cenomanian–Turonian boundary section in the Ultrahelvetic Zone (Eastern Alps, Upper Austria). Cretaceous Research **29**, 965-975.

Wagreich, M. & Faupl, P. (1994): Palaeogeography and geodynamic evolution of the Gosau Group of the Northern Calcareous Alps (Late Cretaceous, Eastern Alps, Austria). Palaeogeography, Palaeoclimatology, Palaeoecology **110**, 235-254.

Wagreich, M. & Krenmayr, H-G (1993): Nannofossil biostratigraphy of the Late Cretaceous Nierental Formation, Northern Calcareous Alps (Bavaria, Austria). Zitteliana, **20**: 67-77.

©Geol. Bundesanstalt, Wien; download unter www.geologie.ac.at

Wagreich, M. & Krenmayr, H.-G. (2005): Upper Cretaceous oceanic red beds (CORB) in the Northern Calcareous Alps (Nierental Formation, Austria): slope topography and clastic input as primary controlling factors. Cretaceous Research, **26**, 57-64.

Ward, P.D. & Kennedy, W. J. (1993): Maastrichtian Ammonites from the Biscay Region (France, Spain). Journal of Paleontology (supplement to vol. 67/5); The Paleontological Society, Memoir **34**, 1-58.

Wicher, C.A. (1956): Die Gosau-Schichten im Becken von Gams (Österreich) und die Foraminiferengliederung der höheren Oberkreide der Tethys. Paläontologische Zeitschrift **30**, 87-136.

ZOBODAT - www.zobodat.at

Zoologisch-Botanische Datenbank/Zoological-Botanical Database

Digitale Literatur/Digital Literature

Zeitschrift/Journal: Berichte der Geologischen Bundesanstalt

Jahr/Year: 2009

Band/Volume: 78

Autor(en)/Author(s): Wagreich Michael, Kollmann Heinz Albert, Egger Hans, Grachev Andrei F., Summesberger Herbert

Artikel/Article: Excursion Guide to RECCCE Workshop 49-74